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Costs of Remedial Actions at Uncontrolled Hazardous Waste Sites -- Impacts of Worker Health and Safety Considerations

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COSTS OF REMEDIAL ACTIONS AT UNCONTROLLED HAZARDOUS WASTE SITES -- IMPACTS OF WORKER HEALTH AND SAFETY CONSIDERATIONS

by

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16. ABSTRACT

Cost-effectiveness evaluations of Superfund expenditures require consideration of additional costs of protecting workers' health and safety. Unfortunately, not much cost data has been available concerning health and safety considerations. This paper represents part of the effort to identify and estimate costs associated with protection of worker health and safety. Although the findings and results cannot be considered the final answer, they will help site management and planning personnel to generalize health and safety cost impacts. The paper is for presentation at the Fourth Management of Uncontrolled Hazardous Waste Sites Conference, October 1983, Washington, D. C.

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INTRODUCTION

In December 1980, the U.S. Congress passed legislation entitled "The Comprehensive Environmental Response, Compensation, and Liability Act" which is also known as Superfund. Superfund provides the U.S. Environmental Protection Agency (EPA) with the legislative mandate and the monetary base to assist in the elimination of public health hazards posed by uncontrolled hazardous waste sites. Section 105 of the Superfund legislation requires the EPA to investigate the costs of remedial/clean-up actions at uncontrolled waste sites. Specifically, Item 2 of Section 105 requires the development of cost ranges for various types of remedial actions.

Responsibility for implementing Superfund actions and response to uncontrolled hazardous waste sites rests primarily with the EPA Office of Emergency and Remedial Response (OERR). At the request of OERR, the EPA Office of Research and Development (ORD) has been conducting research on the costs of remedial actions to fulfill the requirements of Section 105. In support of these activities, several studies have been conducted to evaluate the types of remedial actions and associated costs applicable to Superfund sites (i.e., sites for which Superfund monies have been allocated) and other hazardous waste sites.

In these studies, costs associated with health and safety of workers were either not included or not uniformly identifiable as separate cost items. As a result, the project conducted and being presented in this paper was designed to specifically address the additional costs of protecting worker health and safety on a hazardous waste site. These costs do not include costs associated with addressing concerns

of the public health and safety in the vicinity around an uncontrolled hazardous waste site. However, the controls and costs associated with protection of workers on the site should reflect much, if not at all, of the additional costs of protecting the public in areas removed from the source of contamination (i.e., the hazardous waste site itself).

The objectives of this project were:

1. Identify categories of health and safety costs.
2. Collect and compile health and safety cost estimates and determine a range of costs which can be encountered on hazardous wastes sites.
3. Calculate percentage incremental health and safety cost adjustment factors.
4. Identify factors which impact health and safety costs and should be considered for future study and evaluation.

STUDY DESIGN AND APPROACH

Initial data collection was based on reviews of case studies, bid documents for Superfund sites, and a telephone survey of firms and regulatory agencies. After reviewing available data and the summaries of the telephone survey, it was determined that health and safety costs could not be readily identified. Normal accounting practices did not distinguish many health and safety costs. Such costs were routinely incorporated into general categories such as labor rates, equipment O&M costs, and overhead expenditures. In addition, extensive analysis of cost data from existing sites was viewed by many contractors as extremely sensitive due to competitive and proprietary considerations. On the other hand, most of the contacts felt that general discussions of costs would be of little value because of site specific considerations which impact on the overall costs and particularly health and safety costs. As a result, it was concluded that realistic, but fictious, hazardous waste site scenarios would provide the best format for providing and evaluating cost estimates for remedial action unit operations. In fact, several of the contacts indicated they felt it was the only reasonable approach.

From previous studies and case history reports, 28 discrete remedial action activities (hereafter referred to as remedial action unit operations) were identified. Table 1 is a list of the 28 remedial action unit operations. The basis of classification was the media that the remedial actions control. The media include surface water, ground water, subsurface gas, and waste. Nine of these are classified as surface water controls, eight as ground water controls, three as gas migration controls, and eight as waste controls.

Ten health and safety cost components were identified based on literature reviews, previous site observations, discussions with field personnel from state and federal regulatory officials, and discussions with cleanup contractors. Table 2 is a list of the ten health and safety cost categories identified.

In providing cost estimates, contractors were requested not to address costs of transportation and disposal. This approach was taken due to the amount of information available on transportation and disposal costs and to minimize the amount of cost estimations required of the contractors responding to the scenarios. A separate telephone survey was conducted involving 11 transportation firms to identify current ranges of transportation costs for hazardous waste.. Disposal cost estimates were obtained from the 1981 update of the U.S. EPA report entitled, "Review of Activities of Major Firms Involved in Commercial Hazardous Waste Management Industry" [1]. Since transportation and disposal costs are often included as separate line item costs, separation of these costs in the scenarios is consistent with normal contractor procedures.

TELEPHONE SURVEY

An extensive telephone survey was made to identify available sources of data on health and safety costs. The survey included:

TABLE 1

REMEDIAL ACTION UNIT OPERATIONS

Surface Water Controls

1. Surface Sealing with Synthetic Membrane
2. Surface Sealing with Clay
3. Surface Sealing with Asphalt
4. Surface Sealing with Fly Ash
5. Revegetation
6. Contour Grading
7. Surface Water Diversion Structures
8. Basins and Ponds
9. Dikes and Berms

Ground Water Controls

1. Well Point System
2. Deep Well System
3. Drain System
4. Injection System
5. Bentonite Slurry Trenches
6. Grout Curtain
7. Sheet Piling Cutoff
8. Grout Bottom Sealing

Gas Migration Controls

1. Passive Trench Vents
2. Passive Trench Barriers
3. Active Gas Extraction Wells

Waste Controls

1. Chemical Injection
2. Chemical Fixation
3. Excavation
4. Leachate Recirculation
5. Treatment of Contaminated Water
6. Drum Processing
7. Bulk Tank Processing
8. Transformer Processing

TABLE 2

HEALTH AND SAFETY COST COMPONENT CATEGORIES

1. Decontamination
2. Emergency Preparedness
3. Hazard Assessment
4. Insurance
5. Manpower Inefficiencies
6. Medical Services/Surveillance
7. Personal Protection
8. Personnel Training
9. Record Keeping
10. Site Security

- Forty-seven firms with experience in remedial action responses on hazardous waste sites.
- Eleven state and federal regulatory agency representatives involved with management and/or assessment of hazardous waste site cleanup operations.
- Eight military contacts involved in the management and/or assessment of military hazardous waste sites.
- Six consulting firms that have conducted studies concerned with remedial actions on hazardous waste sites.
- Three research oriented institutions involved in hazardous waste management research activities.

Each telephone interview was recorded on a written telephone summary report, evaluated, and rated based on the following four general criteria:

1. Amount of experience in assessment and management of remedial actions on hazardous waste sites.
2. The variety of experiences with types of sites and/or remedial actions.
3. Access to available data.
4. Willingness to cooperate in providing data and discussing cost allocations.

HAZARDOUS WASTE SITE COSTING SCENARIOS

Six hazardous waste site scenarios were developed to be representative of three basic types of sites:

1. Subsurface Burial
2. Surface Impoundments
3. Above-Grade Storage

Whenever possible, these scenarios were developed based on actual cleanup operations either completed, in progress, or planned for the future. This approach was adopted to ensure that the scenarios would reflect realistic site conditions while providing a means of controlling site variables which could impact cost estimates.

Each scenario was composed of a number of distinct unit operations. The combination of the unit operations represented a complete remedial

action program for each hypothetical site. Site characteristics (e.g., size, topography, hydrology, weather, etc.) were defined for each scenario to provide a detailed profile on the site. Similarly, the characteristics of the wastes present on each site were defined such that the degree-of-hazard conditions could be determined for each unit operation. The degree-of-hazard conditions described represented conditions which parallel four levels of personal protection recommended in the Interim Standard Operating Safety Guides developed by the Office of Emergency and Remedial Response, Hazardous Response Support Division, U.S. Environmental Protection Agency. [2] Table 3 provides a brief description of the conditions associated with the four levels of personal protection (designated as Levels A, B, C, and D in order of decreasing degree-of-hazard conditions). Contractors were instructed to utilize the recommended guides in determining the level of personal protection required.

Contractors providing cost estimates were instructed to provide cost estimates for each unit operation under the conditions set forth in the scenario and costs representative of conducting the same activity if the hazardous wastes were not on-site (i.e., base construction costs). In order to identify the relative impact of variations in degree-of-hazard conditions, contractors were also instructed to provide cost estimates based on three other modifications of hazard conditions which were also specified. The modifications were based only on variations of waste characteristics while all other site conditions and activities remained constant.

One additional factor identified which may significantly impact health and safety costs is ambient temperature. To identify the relative impact of temperature, contractors were instructed to provide an estimate of the cost variations of the total scenario, health and safety costs estimated for each of the four degree-of-hazard conditions. The cost estimate variations were based on the costs under the range of temperatures given in the scenario and two additional temperature ranges. The result was an estimate of total scenario health and safety

TABLE 3

CONDITIONS ASSOCIATED WITH LEVELS OF PERSONAL PROTECTION

1. Level A - requires full encapsulation and protection from any body contact or exposure to materials (i.e., toxic by inhalation and skin absorption).

2. Level B - requires self-contained breathing apparatus (SCBA), and cutaneous or percutaneous exposure to unprotected areas of the body (i.e., neck and back of head) is within acceptable exposure standards (i.e., below harmful concentrations).

3. Level C - hazardous constituents known; protection required for low level concentrations in air; exposure of unprotected body areas (i.e., head, face, and neck) is not harmful.

4. Level D - no identified hazard present, but conditions are monitored and minimal safety equipment is available.

costs under the four degree-of-hazard conditions for low (<0°C), normal (0-18°C), and high (18-38°C) ambient temperature ranges. The relative temperature ranges included wind chill considerations.

The selection of contractors to respond to the scenarios was based on the following criteria:

- Their relative rating provided from the evaluation of the telephone survey results.
- A match of their previous experience with sites similar to one or more of the scenarios.
- The availability of personnel routinely involved in cost estimation and familiar with health and safety requirements on a hazardous waste site.
- Project funding limitations for payment of subcontractors (i.e., site cleanup contractors) to provide cost estimates.

The final selection included seven hazardous waste cleanup contractors responsible for one to three scenarios apiece. Each scenario was assigned to two different contractors for cost estimation.

A questionnaire was also sent to the contractors providing cost estimates. The questionnaire was designed to identify differences in approaches to health and safety considerations which impact costs. The purpose of requesting the information was to provide additional information to assist in determining probable reasons for cost variations anticipated. In addition, contractors were requested to comment on other considerations or differences, if any, that they considered significant.

TRANSPORTATION COST SURVEY

Initial literature search and review was based on (1) in-house library sources, and (2) the U.S. EPA Research Library in the Environmental Research Center in Cincinnati, Ohio. The available literature did not specifically address transportation costs for hazardous waste cleanup sites. Very little current data (1980 to 1982) was available for hazardous materials transportation costs. Additional

efforts were made to identify cost information from current studies. Unfortunately, none of the data was available.

In order to obtain current cost data, a telephone survey of transportation companies and services was conducted. A telephone interview questionnaire was developed for data collection from companies contacted. Eleven companies were contacted. A total of six responses were obtained and can be categorized into three major groups:

1. Companies concentrating or specializing in transportation of hazardous wastes.
2. Companies whose main interests and efforts involve general freight and commodities and only limited involvement in hazardous waste transportation.
3. Waste disposal and treatment companies who provide transportation services for their customers.

Two responses were obtained from companies in each category.

RESULTS AND DISCUSSION

Responses to Scenarios

A total of eleven completed remedial action costing scenarios were returned. Two contractors could not provide the requested cost estimates within the required time period due to conflicting work schedules. As a result, cost estimates for Scenario 5 were provided by only one contractor. The remaining Scenarios 1, 2, 3, 4, and 6 were estimated by two contractors apiece.

The original cost estimates were reviewed and modifications were made (e.g., assigning travel and per diem costs to base construction costs instead of health and safety costs, correction of calculation errors, etc.). Additional information was requested, as necessary, to reallocate costs to uniformly cover the health and safety cost component items. Modifications were reviewed with the respective contractors. Cost estimates were provided for the four degree-of-hazard conditions which were established in the scenarios. The degree-

of-hazard conditions were identified as Levels A, B, C, and D which indicate maximum level of personal protection required based on the information given in the scenario information/instruction packets sent to the contractors. The degree-of-hazard condition designated Level A as the worst case, while Level D is the least hazardous condition.

In Scenario 2, costs were only requested for Level C conditions which were considered sufficient for worker protection for handling PCB's. The scenario was included because of the number of sites and public concern involving electrical equipment containing PCB's and the special requirements established for PCB's by the Toxic Substances Control Act (TSCA).

The contractor's cost estimates were compiled and evaluated, then used to calculate a cost per unit range for each remedial action unit operation. Cost per unit calculations were made for health and safety costs at the four degree-of-hazard conditions and for base construction costs. Table 4 shows the cost per unit ranges calculated. A percentage incremental cost factor was calculated by dividing the health and safety costs per unit for each of the degree-of-hazard conditions by the costs per unit calculated for the base construction costs. The resulting percent range of incremental health and safety cost adjustment factors are presented in Table 5. Estimates for those remedial action unit operations not costed as part of the six cost scenarios can be calculated based on a comparison of potential worker exposures while conducting remedial action unit operations. The types of activities which determine the potential for worker exposures were identified for each of the 28 remedial action unit operations as presented in Table 6.

The estimated impacts of temperature on remedial action costs are summarized in Table 7. The original estimates did provide costs for each unit operation, but the specific component costs which contractors considered temperature sensitive and the amount of the impact were not

TABLE 4

RANGE OF HEALTH AND SAFETY COSTS PER UNIT*

Unit Operation	Unit of Measure	Base Construction Costs Per Unit	Health and Safety Costs Per Unit			
			Level D	Level C	Level B	Level A
Surface Water Controls:						
Surface Seal - Synthetic Membrane	m^2	$14.41-$19.65	$1.13-$3.99	$2.06-$4.63	$2.41-$5.49	$2.48-$5.93
Surface Seal - Clay	sq yd	$17.24-$23.50	$1.35-$4.77	$2.46-$5.53	$2.88-$6.56	$2.97-$7.09
Revegetation+	m^2	$2.74	$0.26	$0.52	$0.66	$0.74
	sq yd	$2.29	$0.22	$0.43	$0.55	$0.62
	ha	$6,372-$124,000 #	$340-$65,115	$1,215-$73,342	$1,215-$74,940	$1,215-$78,637
	acre	$2,549-$49,600	$136-$26,046	$486-$29,337	$486-$29,976	$486-$31,455
Contour Grading	m^3	$2.95-$5.76	$0.38-$2.10	$0.73-$2.66	$0.96-$3.02	$0.97-$3.70
	cu yd	$2.22-$4.40	$0.29-$1.61	$0.56-$2.03	$0.73-$2.31	$0.75-$2.83
Surface Water Diversion	m^3	$1.91-$16.05 **	$0.23-$9.13	$0.38-$10.72	$0.46-$12.34	$0.47-$13.34
	cu yd	$1.46-$12.28	$0.17-$6.99	$0.29-$8.20	$0.35-$9.44	$0.36-$10.20
Basins and Ponds	m^3	$4.52-$8.53	$0.41-$3.45	$0.93-$4.60	$1.28-$5.22	$1.59-$5.58
	cu yd	$3.46-$6.52	$0.31-$2.64	$0.71-$3.52	$0.98-$3.99	$1.21-$4.27
Dikes and Berms	m^3	$12.78-$15.96	$0.84-$14.68	$2.65-$19.94	$3.04-$20.91	$3.35-$23.31
	cu yd	$9.78-$12.21	$0.65-$11.23	$2.03-$15.26	$2.33-$16.00	$2.57-$17.83
Ground Water Controls:						
Well Point System	m^2	$133	$11.70	$19.63	$24.06	$31.34
	sq yd	$111	$9.78	$16.41	$20.12	$26.20
Drain System	m^3	$38.87-$49.22	$3.31-$22.99	$6.17-$29.75	$7.51-$32.46	$10.60-$34.06
	cu yd	$29.72-$37.63	$2.53-$17.58	$4.72-$22.75	$5.74-$24.82	$8.10-$26.04
Bentonite Slurry Trench	m^3	$50.96	$4.46	$6.97	$16.40	$18.24
	cu yd	$38.97	$3.41	$5.33	$12.54	$13.94
Waste Controls:						
Chemical Fixation (Solidification)	m^3	$25.06-$147.33	$2.75-$46.62	$4.12-$60.97	$4.29-$70.04	$4.64-$80.38
	cu yd	$19.16-$112.63	$2.10-$35.64	$3.15-$46.61	$3.28-$53.54	$3.55-$61.45
Excavation of Wastes/Contaminated Soil	m^3	$3.10-$324.41	$14.52-$112.10	$5.90-$246.42	$24.70-$169.38	$28.99-$198.02
	cu yd	$2.37-$248.08	$11.11-$85.72	$4.51-$188.44	$18.88-$129.53	$22.17-$151.43
Treatment of Contaminated Water	l/day	$0.09-$1.[illegible]	$0.01-$5.35	$0.01-$5.44	$0.02-$6.14	$0.02-$6.97
	gpd	$0.35-$53.49	$0.03-$20.27	$0.05-$20.59	$0.06-$23.22	$0.08-$26.37
Drum Processing	208 l (55 gal) drums	$36.18-$630.89	$51.94-$928.42	$69.63-$1,165.63	$88.89-$1,402.86	$102.68-$1,690.07
Bulk Tank Processing	30,280 l (8,000 gal) tanks	$1,222-$4,032	$1,047-$4,162	$1,926-$5,560	$5,670-$6,958	$8,354-$8,434
Transformer Processing	Transformer	$210-$330	--	$48.57-$1,196	--	--

* Cost ranges are not adjusted for economy of scale or regional variations.
\+ Range includes cost estimates from one contractor which were significantly higher than the others.
\# A composite of base construction costs for revegetation from previous SCS report [3] yields a range of $3,974 - $18,079 per ha ($1,603 - $7,300 per acre).
** Costs from previous SCS report [3] yield cost ranges of $1.75 - $3.63 per m^3 ($1.34 - $2.78 per cu yd) for surface water diversion base construction.

TABLE 5

INCREMENTAL HEALTH AND SAFETY COSTS -- RANGE OF PERCENTAGE ADJUSTMENTS OVER BASE CONSTRUCTION COSTS

Unit Operation	Degree-of-Hazard Conditions			
	Level D	Level C	Level B	Level A
Surface Water Controls:				
1. Surface Sealing - Synthetic Membrane	8-20%	14-24%	17-28%	17-30%
2. Surface Sealing - Clay	9%	19%	24%	27%
3. Surface Sealing - Asphalt	--	--	--	--
4. Surface Sealing - Fly Ash	--	--	--	--
5. Revegetation	5-53%	12-59%	13-60%	14-63%
6. Contour Grading	9-45%	17-57%	22-65%	24-80%
7. Surface Water Diversion Structures	12-57%	20-67%	24-77%	25-83%
8. Basins and Ponds	9-40%	21-54%	28-61%	35-65%
9. Dikes and Berms	7-92%	21-125%	24-131%	26-146%
Ground Water Controls:				
1. Well Point System	10%	17%	21%	28%
2. Deep Well System	--	--	--	--
3. Drain System	9-47%	16-60%	19-66%	27-69%
4. Injection System	--	--	--	--
5. Bentonite Slurry Trench	9%	14%	32%	36%
6. Grout Curtain	--	--	--	--
7. Sheet Piling Cutoff	--	--	--	--
8. Grout Bottom Sealing	--	--	--	--
Gas Migration Controls:				
1. Passive Trench Vents				
2. Passive Trench Barriers				
3. Active Gas Extraction Systems				
Waste Controls:				
1. Chemical Fixation (Solidification)	11-32%	16-41%	17-48%	19-55%
2. Chemical Injection	--	--	--	--
3. Excavation of Wastes/Contaminated Soil	32-545%	44-613%	50-785%	58-1990%
4. Leachate Recirculation	--	--	--	--
5. Treatment of Contaminated Water	11-38%	11-38%	22-43%	22-49%
6. Drum Processing	32-166%	75-192%	50-277%	58-353%
7. Bulk Tank Processing	86-103%	138-158%	173-464%	209-690%
8. Transformer Processing	--	23-36 %	--	--

TABLE 6

ACTIVITIES WHICH IMPACT POTENTIAL WORKER EXPOSURES WHILE CONDUCTING REMEDIAL ACTIONS ON HAZARDOUS WASTE SITES

Unit Operation	Excavation of Soils/Wastes	Injection, Drilling, Boring and Driving into Soils/Wastes	Grading and Filling	Direct Handling/Processing Media	Exposures to Vapors
Surface Water Controls:					
1. Surface Sealing - Synthetic Membrane	•		•		
2. Surface Sealing - Clay	•		•		
3. Surface Sealing - Asphalt	•		•		
4. Surface Sealing - Fly Ash	•		•		
5. Revegetation			•		
6. Contour Grading			•		
7. Surface Water Diversion Structures			•		
8. Basins and Ponds	•		•		o
9. Dikes and Berms	•		•	•	o
Ground Water Controls:					
1. Well Point System		•		•	•
2. Deep Well System		•		•	•
3. Drain System	•		•	•	•
4. Injection System		•		•	•
5. Bentonite Slurry Trench	•		•	o	•
6. Grout Curtain		•		o	•
7. Sheet Piling Cutoff		•			•
8. Grout Bottom Sealing		•		•	•
Gas Migration Controls:					
1. Passive Trench Vents	•		•	o	•
2. Passive Trench Barriers	•		•	o	•
3. Active Gas Extraction Systems	•			•	•
Waste Controls:					
1. Chemical Fixation (Solidification)	•		•	•	•
2. Chemical Injection		•		•	
3. Excavation of Wastes/Contaminated Soil	•		•	•	
4. Leachate Recirculation		•		•	•
5. Treatment of Contaminated Water				•	•
6. Drum Processing	o			•	•
7. Bulk Tank Processing	o			•	•
8. Transformer Processing	o			•	•

• Denotes applicability.
o Denotes applicability if done in contaminated area.

TABLE 7

IMPACT OF TEMPERATURE ON REMEDIAL ACTION COSTS

Contractor-Scenario	Temperature °C	Temperature °F	Health and Safety Costs: Level D $	Level D %	Level C $	Level C %	Level B $	Level B %	Level A $	Level A %	Base Construction $	Base Construction %
I-1	0-18°	32-65°	542,921	186	632,693	216	843,502	288	1,132,788	387	292,636	100
	18-38°	65-100°	554,633	190	702,569	240	1,067,258	364	1,406,375	480	300,156	102
	<0°	<32°	553,980	189	651,717	223	898,484	307	1,203,433	411	299,069	102
II-1	0-18°	32-65°	181,993	35	215,083	41	248,173	47	281,262	54	523,763	100
	18-38°	65-100°	272,990	52	322,625	62	372,259	71	421,893	81	654,704	125
	<0°	<32°	242,051	46	286,060	55	300,070	63	374,078	71	591,852	113
I-2	0-18°	32-65°	--	--	96,212	29	--	--	--+	--	326,905	100
	18-38°	65-100°	--	--	139,694	43	--	--	--	--	346,818	106
	<0°	<32°	--	--	132,142	40	--	--	--	--	382,466	117
III-2	0-18°	32-65°	--	--	1,847,859	146	--	--	--	--	579,239	100
	18-38°	65-100°	--	--	1,999,002	345	--	--	--	--	608,201	105
	<0°	<32°	--	--	1,976,913	341	--	--	--	--	637,163	110
II-3	0-18°	32-65°	239,184	225	282,672	266	326,160	307	369,648	348	106,293	100
	18-38°	65-100°	263,102	248	310,939	293	358,776	338	406,613	383	116,922	110
	<0°	<32°	318,115	299	375,954	354	433,792	408	491,632	463	120,111	113
IV-3	0-18°	32-65°	83,909	35	121,689	50	136,845	56	151,865	47	243,044	100
	18-38°	65-100°	85,036	35	123,741	51	139,921	58	160,677	66	253,927	104
	<0°	<32°	84,923	35	123,536	51	139,653	57	157,851	65	251,044	101
III-4	0-18°	32-65°	1,083,950	30	2,586,279	72	4,840,374	135	5,632,913	157	3,578,034	100
	18-38°	65-100°	1,104,892	31	2,690,078	75	5,326,286	149	6,440,973	180	3,805,192	106
	<0°	<32°	1,140,992	32	2,732,903	76	5,315,501	149	6,185,373	173	4,145,229	116
IV-4	0-18°	32-65°	152,055	8	276,819	14	322,347	17	341,186	18	1,946,303	100
	18-38°	65-100°	154,267	8	284,368	15	351,174	18	374,881	19	1,956,759	101
	<0°	<32°	*126,037	4	*232,442	57	*258,518	64	*281,424	70	407,841	101
IV-5	0-18°	32-65°	121,434	9	191,175	14	380,581	28	432,941	32	1,364,876	100
	18-38°	65-100°	123,564	9	194,504	14	409,655	30	467,512	34	1,379,281	101
	<0°	<32°	*118,746	34	*167,207	48	*213,120	61	*258,411	74	*349,836	101
III-6	0-18°	32-65°	374,846	48	461,192	59	459,778	58	490,210	62	787,426	100
	18-38°	65-100°	388,812	49	482,787	61	536,855	72	598,652	76	820,592	104
	<0°	<32°	384,098	49	456,403	58	486,169	62	513,582	65	814,315	103
V-6	0-18°	32-65°	17,283	11	26,275	17	28,584	18	31,094	20	159,005	100
	18-38°	65-100°	17,283	11	28,139	18	33,239	21	39,908	25	161,915	102
	<0°	<32°	17,283	11	28,139	18	33,239	21	39,908	25	161,915	102

* Partial costs excluding unit operations considered infeasible at lower temperature ranges.
\+ Not available since this Scenario 2 was only applicable to (and priced at) Level C.

Note: Percentages provided are relative to base construction costs for 0-18°C temperature range.

identified. Therefore, revisions of original cost estimates, after review of data and follow-up telephone contacts, prevented direct modification of individual unit operations. However, general indications of temperature impacts can be drawn from the data provided. The percent variations were based on increases above base construction costs estimated for the moderate 0 to 18°C range. As shown in Table 7, base construction costs and health and safety increased with higher or lower temperatures. Use of an average variation (as shown in Table 8) would enable general estimate adjustments relative to the impact of anticipated seasonal or climatic temperature differences.

Transportation and Disposal Costs

The costs of transportation of hazardous wastes varies widely with respect to specific jobs and the type of company employed to transport the wastes. In addition, the lack of standardized rates can result in even more variation depending on the amount of competition for a given job. The ranges obtained from this survey should reflect cost for most of the hazardous waste transportation, but will not reflect unusual costs associated with some sites.

Rates can be based on costs per mile, cost per unit measure (i.e., volume and/or weight of cargo) or a cost per hour. A cost per mile rate assumes full use of vehicle load capacity. Economies of scale will apply to cost per mile and cost per unit measure rates. This is true for mileage rates because the cost effectiveness of operation is greater when the ratio of time on the road increases over the down time spent for mobilizing, loading, and unloading. When rates are based on cost per unit measure, the cost per unit will decrease as load capacity is approached since the cost of transporting (i.e., costs previously identified) are divided among more units. Hourly rates normally are applied to short hauls (due to the increase in percentage of down time), jobs which involve indefinite loading and

TABLE 8

AVERAGE PERCENT COST VARIATIONS DUE TO TEMPERATURE

Temperature Ranges °C	Temperature Ranges °F	Base Construction	Level D Health & Safety	Level D Total*	Level C Health & Safety	Level C Total*	Level B Health & Safety	Level B Total*	Level A Health & Safety	Level A Total*
0-18°	32-65°	100	65	165	84	184	106	206	125	225
18-38°	65-100°	106	70	176	111	217	125	255	149	255
<0°	<32°	107	78	185	120	227	132	239	157	264

* Total = Health & Safety Costs Plus Base Construction Costs.

unloading periods, and for additional costs of detention times exceeding the time allocated (included in the cost per mile or cost per unit measure rates). Table 9 contains the ranges of rates obtained during the survey. Table 10 is a range of costs provided by one of the general freight transporters which provides an indication of the impact of distance on rates.

The disposal costs used for this project (shown in Table 11) were obtained from an EPA publication "Review of Activities of Major Firms in the Commercial Hazardous Waste Management Industry: 1981 Update", SW-894.1. As indicated on the table, the data was based on interviews conducted in May 1980 and February 1982. The assumptions made to convert estimates to $/wet metric tons (WMT), when conversion factor estimates were not available, were reported to be:

- Volumes in gallons were converted to WMT assuming the waste density was that of water (i.e., 8.34 lb/gal or 0.0037 WMT/gal).
- Cubic yards were converted to WMT on the assumption of density equal to water at 62.4 lb/cu ft or 0.76 WMT/cu yd.
- Volumes disposed of in landfills were assumed to be bulk materials unless drum and bulk distribution was stated.
- Capacity reported in acres was converted to WMT by assuming available capacity of 430,000 cu ft/acre or a disposal capacity of 12,100 WMT/acre.

SUMMARY AND CONCLUSION

Cost-effectiveness evaluations of Superfund expenditures require consideration of additional costs of protecting workers' health and safety. Unfortunately, not much cost data has been available concerning health and safety considerations. This study represents part of the effort to identify and estimate costs associated with protection of worker health and safety. Although the findings and results of this project cannot be considered the final answer, they will enable site management and planning personnel to generalize health and safety cost impacts.

TABLE 9

RANGES OF TRANSPORTATION COSTS BY TYPE OF TRANSPORTER

Type of Transporter	Rates ($/km)
Treatment, Storage, and Disposal Facilities Providing Service to Customers	$0.75-$2.57
General Freight Transportation Companies Which May Haul Hazardous Wastes on Request	$0.75-$3.73
Hazardous Waste Transportation Companies Specializing in Hazardous Wastes	$1.99-$2.60

* Range based on 320 to 1,609 km (200 to 1,000 miles) distance for one-way shipment at $3/220.5 kg (100 lbs).

TABLE 10

RATE SCHEDULES FOR VARIOUS DISTANCES AND GEOGRAPHIC LOCATIONS

Distance (km)	Destination Rates* One-Way		Round Trip
	East of the Mississippi	West of the Mississippi	
370	$1.62	$1.78	$1.27
560	1.34	1.51	1.01
740	1.16	1.34	0.86
1,110	0.96	1.15	0.74+
1,480	0.86	1.05	0.74
1,850	0.81+	1.00	0.74
≥4,630	0.81	0.90+	0.74

* Rates quoted in dollars per km.
+ Minimum rate-remains constant for all distances above that shown.

TABLE 11

COMPARISON OF HAZARDOUS WASTE MANAGEMENT QUOTED PRICES FOR ALL FIRMS IN 1980 AND FOR NINE MAJOR FIRMS IN 1981*

Type of Waste Management	Type or Form of Waste	Price		$/Metric Ton	
		1980	1981	1980	1981
Landfill	Drum	$25-$35 $/55 gal drum	$35-$50/55 gal drum	$120-$168	$168-$240
	Bulk	$40-$50/ton	$50-$75/ton	$44-$55	$55-$83
Land Treatment	All	$0.02-$0.09/gal	$0.02-$0.09/gal	$5-$24	$5-$24
Incineration	Relatively clean liquids, high Btu value	$0.20-$0.90/gal	$(0.05)^{+}$-$0.20/gal	$53-$237	$(13)^{+}$-$53
	Liquids	$0.20-$0.90/gal	$0.20-$0.90/gal	$53-$237	$53-$237
	Solids, heavily toxic liquids	$1.25-$2.50/gal	$1.50-$3.00/gal	$330-$660	$395-$791
Chemical Treatment	Acids/Alkalines	$0.06-$0.30/gal	$0.08-$0.35/gal	$16-$79	$21-$92
	Cyanides, heavy metals, highly toxic wastes	$0.20-$2.00/gal	$0.25-$3.00/gal	$53-$528	$66-$791
Resource Recovery	All	$0.19-$0.80/gal	$0.25-$1.00/gal	$50-$211	$66-$264
Deep Well Injection	Oily wastewaters	$0.06-$0.15/gal	$0.06-$0.15/gal	$16-$40	$16-$40
	Toxic rinse waters	$0.50-$1.00/gal	$0.50-$1.00/gal	$132-$264	$132-$264
Transportation			$0.15/ton mile		

* Interviews were conducted in May of 1980 and February of 1982.
\+ Some cement kilns and light aggregate manufacturers are now paying for wastes.

Source: U.S. Environmental Protection Agency. "Review of Activities of Major Firms in the Commerical Hazardous Waste Management Industry: 1981 Update". SW-894.1. May 1982.

Several factors which impact cost were identified, but not addressed within the scope of this project. These include:

- Scale Economies
- Regional Differences
- Management Policies and Procedures
- Type and Size of Company

Previous studies have shown scale economies and regional variations to be significant in construction costs. It would be reasonable to assume similar impacts on health and safety costs, however, it was not possible to quantify the impact of these factors based on the existing data.

During the course of this project, differences in the management procedures and policies were identified which impacted the cost estimates provided. Currently, there are no regulatory standards which are uniformly enforced on hazardous waste sites. Therefore, the impact of safety management policies and procedures of individual contractors can significantly impact health and safety costs. In addition, the emphasis placed by a given contractor on the use of equipment versus manpower to accomplish the tasks required, can also impact the health and safety costs due to the differences in the exposure potential for workers operating machinery versus workers directly handling containers and/or contaminated materials.

The type and size of companies involved will impact their ability to make most efficient use of equipment and personnel. Large companies with deep resources and a backlog of work projects can coordinate the use of equipment and personnel among projects to be more cost-efficient. However, smaller companies or specialty firms with smaller resources and fewer projects may incur higher costs in order to maintain a qualified staff and cover overhead expenses of idle equipment.

Use of the data from this report should include evaluation of possible impacts of these factors.

The primary result of this report is a means to adjust remedial action cost estimates to reflect additional costs of health and safety considerations. This may involve adding these health and safety costs to engineering study cost estimates based on standard construction cost estimates, or adjusting cost estimates from actual sites. Adjustments made will reflect the costs associated with variations in the degree-of-hazard conditions on the site being evaluated. Additional applications may include:

- Calculation of costs for various applications of unit operations. For example, the cost of constructing a drain system for leachate collection could be evaluated for on-site versus off-site locations. The added costs for increasing the intercept area off-site could be compared with the added costs of worker safety and health considerations for a smaller system installed in the contaminated areas on-site.

- Planning of site assessment activities prior to initiation of remedial action activities. The worst degree-of-hazard condition which is anticipated, based on available information, would determine the cost of worker health and safety protection which would be provided. The potential savings of reduced health and safety costs for less hazardous conditions could be calculated. The cost-effectiveness evaluation of conducting more detailed site characterization and waste stream identifications to define degree-of-hazard conditions could then include consideration of potential savings if conducted prior to initiation of remedial actions.

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DISCLAIMER

The information and data presented in this paper do not necessarily reflect the views and policy of the U.S. EPA. This paper was based on the Draft Final Report - Costs of Remedial Actions at Uncontrolled Hazardous Waste Sites -- Worker Health and Safety Considerations which is currently in the U.S. EPA peer review process.

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